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TITLE: Second-Harmonic Axis-Encircling Electron Beam Gyro-TWT Amplifier

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Second-Harmonic Axis-Encircling Electron Beam Gyro-TWT Amplifier

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Abstract: *A Ka-Band TE_{21} second-harmonic gyro-TWT amplifier with a large-orbit axis-encircling beam from a Northrop Grumman Cusp gun is being fabricated and tested at UCD. The device is predicted to produce 50 kW with 20% efficiency, 30 dB saturated gain and 3% bandwidth.*

Keywords: gyro-TWT; axis-encircling; second-harmonic.

Introduction

There is considerable interest in millimeter-wave amplifiers to be used in high-resolution advanced radar and communications applications. The gyro-TWT is an excellent candidate for these applications because of its potential to produce high power at millimeter-wave frequencies with broad bandwidth. There has been significant achievement in fundamental cyclotron frequency mode gyro-TWTs; however, they require superconducting magnets which increases the size, weight and complexity of operating the gyro-TWT.

The required magnetic field for a gyro-TWT for a given frequency of operation is reduced by the number of the cyclotron harmonic; thus, with harmonic operation the gyro-TWT can potentially operate at high frequencies with conventional magnets or even permanent magnets. Unfortunately, gyro-TWTs operating at harmonics with a Magnetron Injection Gun (MIG) suffer a significant loss in efficiency especially at higher harmonics. An axis-encircling beam is more suited to interact in a harmonic device. This is illustrated in Fig. 1. In the case of the MIG, electrons are constrained to a fixed azimuth so some electrons experience a weak RF field, while others oversaturate in a strong field. In the axis-encircling beam, electrons rotate through both the peaks and nulls of the mode yielding a more efficient harmonic interaction.

Recent advances in high quality axis-encircling beam electron guns has renewed interest in the development of harmonic axis-encircling beam gyro-TWTs with their potential for greater efficiency, power and stability. A second-harmonic TE_{21} gyro-TWT is being constructed at UCD that is predicted to produce 50 kW in Ka-band with 20% efficiency, 30 dB saturated gain and 3% bandwidth. The device is driven by a 70 kV, 3.5 A axis-encircling electron beam from a Northrop Grumman cusp gun.

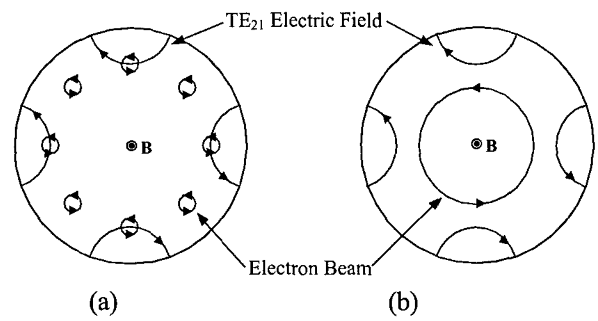

Figure 1. Schematic of electrons interacting with a TE_{21} mode in a circular waveguide for (a) a non-axis-encircling beam and (b) an axis-encircling beam.

Device Stability

For amplifier stability, it is desirable to suppress as many unnecessary circuit modes as possible. The current device employs a sliced mode-selective circuit to suppress odd-order azimuthal modes by interrupting their wall currents [1]. Surrounding the interaction circuit is a lossy cylinder to absorb the radiated power. Figure 2 shows the interaction circuit prior to the lossy component Aquadag® being applied to the dielectric.

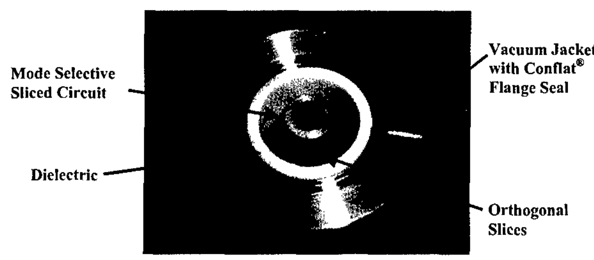

Figure 2. Mode selective sliced circuit.

Furthermore, the gyro-TWT uses the concept of distributed loss [2] to suppress the $TE_{41}^{(4)}$ gyro-BWO mode, the strongest oscillatory threat for this gyro-TWT. The first 30.5 cm of the interaction circuit has a wall resistivity 2300 times that of copper to yield a stable interaction length of $220r_W$ to suppress the $TE_{41}^{(4)}$ mode gyro-BWO. The last 11.5 cm of the 42 cm circuit long

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does not have loss added so that the high power wave is not attenuated.

Magnetic Circuit

The magnetic circuit for the gyro-TWT is designed to provide both the magnetic field reversal required in the cusp gun region and at the same time a constant axial magnetic field of 5.48 kG in the interaction circuit region over the 42 cm length of the circuit.

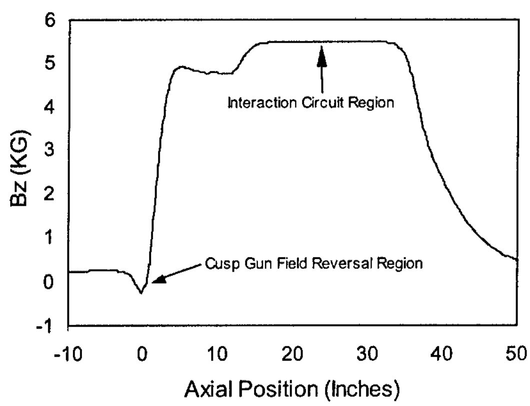

Figure 3. Magnetic field profile simulated in Maxwell2D®.

In addition, the axial magnetic field is designed to ensure that each section of the device is free from oscillation. The magnetic field profile is shown in Fig. 3. The magnetic circuit consists of water cooled copper magnet coils and iron pole pieces. The magnetic field circuit is shown in Fig. 4.

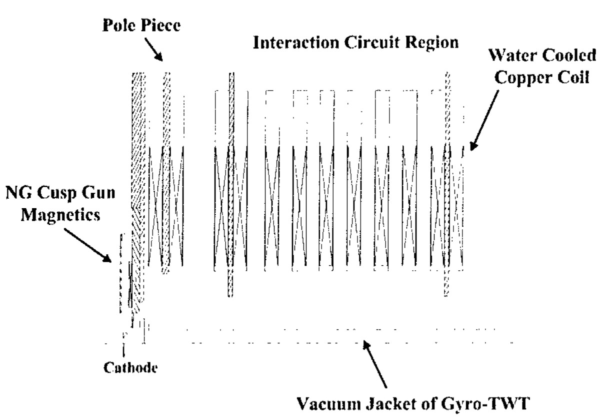

Figure 4. Magnetic circuit

Circuit Components

Figure 5 shows the circuit components including the couplers for the device. The circuit components reside inside the vacuum strongback in the demountable Conflat® flange configuration of the gyro-TWT.

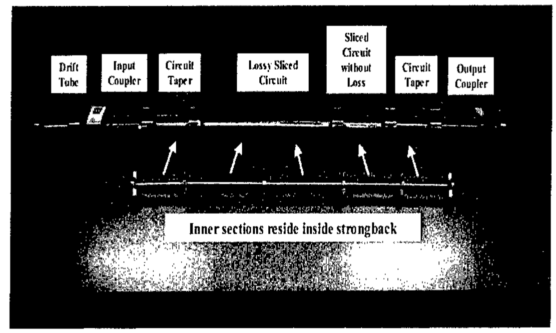

Figure 5. Circuit assembly.

Status/Summary

All the major components for the gyro-TWT have been built. The device is being assembled for hot testing.

References

1. Q.S. Wang, D.B. McDermott and N.C. Luhmann, Jr., *Phys. Rev. Lett.* 75, 4322 (1995).

2. K.R. Chu, et al., *IEEE Trans. Plasma Sci.* 27, 391 (1999).

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